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APPLE SPRAYING EXPERIMENTS IN 1916 and 1917

CONTENTS.

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BULLETIN 271

APPLE SPRAYING EXPERIMENTS IN 1916 AND 1917*

W. J. MORSE.

This publication constitutes the seventh and eighth annual reports of progress with the apple spraying experiments which are being conducted at Highmoor Farm, Monmouth. In 1916 9 and in 1917 10 different plots were used. Each of these plots consisted of 24 trees, or 4 rows of 6 trees to the row, except plot 1 in 1917 had only 23 trees. All were of the Ben Davis variety.

The above mentioned plots were located in the orchard known as "Ben Davis No. 2", which consists of a solid block of 555 trees. Somewhat less than two-fifths or 216 trees in 1916 and nearly three-sevenths or 239 trees in 1917 were included in the experiments.

The very evident value of arsenate of lead as a preventive of apple scab when used alone, as shown in the results obtained in the 4 previous, consecutive seasons seemed to warrant the testing of this material on a larger scale in 1916. Accordingly one-half of the orchard known as "Ben Davis No. 1" was sprayed with lime-sulphur 20 per cent stronger than standard, plus one pound of dry arsenate of lead to 50 gallons for the blossom bud application.† The two remaining applications consisted of double strength arsenate of lead alone. This duplicates

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*A general discussion of the nature and extent of the previously conducted experiments with a summary of the results obtained is given in Bulletin 249 entitled, "Six Years of Experimental Apple Spraying at Highmoor Farm." The results for 1915 are given in Bulletin 252 of this Station.

†By standard dilution lime-sulphur is meant the equivalent of 1 gallon of 33° B. lime-sulphur concentrate to 40 gallons of water. To make the so-called 20 per cent stronger dilution one-fifth more of the concentrate is added to a given amount of water than is used to make the standard dilution.

on a large scale plot 5 of 1916 and plot 3 of 1917. The remainder of the orchard was sprayed with standard dilution lime-sulphur containing one pound of dry arsenate of lead in 50 gallons, thus duplicating plot 1 of 1916 and plot 5 of 1917. This orchard, consisting of over 1200 Ben Davis trees, lies directly across the road from the experimental plots in Ben Davis No. 2.

SPRAYING PROGRAM.

No sprays were used when the trees were dormant. Unless otherwise specified 3 applications were made, the aim being to make the first when the blossom buds were showing pink, the second just after the petals fell, and the third application between two and three weeks after the second. The dates of application each season are given later.

TREATMENT OF PLOTS IN 1916.

Plot 1. Standard dilution lime-sulphur, plus one pound of dry, acid arsenate of lead to 50 gallons.

Plot 2. Same spray treatment as plot 1, but using Friend calyx nozzle.

Plot 3. Standard dilution lime-sulphur plus one pound of arsenate of lime to 50 gallons.

Plot 4. First application omitted, otherwise like plot 1.

Plot 5. Blossom bud application, lime-sulphur 20 per cent stronger than standard dilution, plus one pound of dry, acid arsenate of lead to 50 gallons. Later applications two pounds of dry, acid arsenate of lead alone in 50 gallons.

Plot 6 Dry, acid arsenate of lead alone, two pounds in 50 gallons of water.

Plot 7. Bordeaux mixture, 3-3-50, plus one pound of dry, acid arsenate of lead in 50 gallons.

Plot 8. Sherwin-Williams dry lime sulphur, using for dilution in water 3 pounds of the powder as an equivalent of one gallon of a 33° B. concentrate and adding one pound of dry acid arsenate of lead to each 50 gallons of diluted spray.

Plot 9. Unsprayed check.

Time and Manner of Spray Applications in 1916.

The first spray application was made on the experimental plots on May 20, the second June 5, and the third June 23. Ben Davis orchard No. 1 was sprayed the first time immediately following the experimental plots. On account of weather conditions, which are discussed later in some detail, the completion of the second application was not accomplished till June 13. However, to make conditions uniform, a separate machine and spraying crew were employed in each half of the orchard at the same time. Therefore approximately an equal number of trees were covered with each kind of spray on each day that the work was done. The third application to each half of Ben Davis No. 1 was made on June 26 and 27.

An attempt was made to apply the sprays on the experimental plots with a pressure of 200 pounds, but on account of the failure of the pump to maintain this pressure constantly, 150 to 175 pounds per square inch was used. A type of nozzle which throws a fine mist was used on all but plot 2 where the Friend calyx nozzle was substituted. With this distinctly more spray was applied than with the other type, and some difficulty was experienced when changing from the other form to this in getting the men who handled the spray rods to adjust their movements so as to avoid waste of material, and at the same time do thorough work.

Conditions During and Following the Spraying Season of 1916.

The early part of May was favorable for growth, but cold, rainy weather prevailed for some time previous to the first application. The blossom buds were nearly in condition to spray for 10 days previous to the first application but their development was extremely slow. On the date of application, May 20, all of the buds in each cluster were showing distinctly pink.

The total rainfall recorded at the farm for the month of May was 5.77 inches. The 5 days preceding May 17 were very cloudy and rainy, and 4.09 inches of the total rainfall for the month came during that day and the night following. Some

rain fell on the 18th, and the 19th also was cloudy. Between May 20 and June 5, the date of the second application, there were 7 wholly fair days. Rain fell on 5 different days but this was slight, except on May 30 when .95 of an inch was recorded.

At the time of the second application the petals had not entirely fallen but weather conditions indicated that it was unsafe to delay farther. On this date, June 5, the forenoon was clear but the afternoon was cloudy. Late in the afternoon .05 of an inch of rain fell but this occurred after the plots had been sprayed and the material applied had become dry.

Of the 17 days that intervened between the second and third applications only 3 were recorded as entirely fair. Rain fell on 9 of these days. The total rainfall for June was 4.20 inches, making the combined total for May and June nearly 10 inches. It would seem that the weather conditions just prior to the first application of the sprays and from then on till the third application had been made were extremely favorable for scab infection and development. As will be shown later nearly 39 per cent of the fruit on the unsprayed plot was scabby. Undoubtedly this would have been greatly increased were it not for the fact that the experimental plots were all plowed prior to May 8, thus turning under the diseased leaves of the season before, except those near the bases of the trees, previous to the complete development of the ascospores of the scab fungus upon the leaves, under local climatic conditions.

EFFECT OF THE DIFFERENT SPRAYS ON THE FOLIAGE AND FRUIT DURING THE SUMMER OF 1916.

Plot 1. Standard dilution lime-sulphur and acid arsenate of lead.

A very slight amount of injury to the tips of the leaves was noted on June 22. By the middle of July some burning of the margins was apparent but this was not bad. Russeting of the fruit was quite evident at this time and was plainly greater than on the unsprayed check. These effects did not materially increase during the remainder of the season. After the middle of July a small amount of scab was noted on the leaves but none on the fruit before harvesting.

Plot 2. Same as plot 1, using Friend calyx nozzle.

The record for this plot throughout the season was identical with that for plot 1.

Plot 3. Standard dilution lime-sulphur and arsenate of lime.

The amount of scab and leaf injury was also essentially the same on plot 3 as on plot 1, except that after the first of August the amount of foliage injury on 3 where arsenate of lime had been used with lime-sulphur was considerably more common. This observation was carefully checked since it was unexpected. On the other hand, fruit russeting was less apparent on plot 3 than on plot 1.

Plot 4. Standard dilution lime-sulphur and acid arsenate of lead, first application omitted.

On plot 4, scab on the foliage was as well controlled as on plot 1 where all 3 applications of lime-sulphur and arsenate of lead were made. In comparison with plot 1, plot 4 in the early part of the season showed somewhat less leaf injury.

Plot 5. First application stronger lime-sulphur and acid arsenate of lead; last two, double strength acid arsenate of lead alone.

No leaf injury was recorded. The general condition of the foliage was better than on plot 1 throughout the season, although a slight amount of scab was noted at about the same time that it was observed on the latter.

Plot 6. Acid arsenate of lead alone, double strength.

Scab appeared on the leaves at the same time as on plots 1 and 5 and was evidently somewhat more common. A careful comparison of plot 6 with plot 9, the unsprayed check, showed that on July 18 the number of scabby leaves and fruit were much greater on the latter. It was estimated at that time that the use of arsenate of lead alone as a spray had reduced the amount of scab on the foliage from 90 to 95 per cent.

Plot 7. Bordeaux mixture, 3-3-50, and acid arsenate of lead.

With bordeaux mixture, as in the past, a large amount of leaf injury and defoliation appeared early in the season and much leaf spotting was apparent even up to harvest time. No scab was observed on this plot previous to harvesting.

Plot 8. Sherwin-Williams Co. dry lime-sulphur and acid arsenate of lead.

The appearance of the foliage on this plot did not differ materially from that recorded for conditions on plot 1.

Plot 9. Unsprayed check.

Scab began to appear on the leaves on the unsprayed check before the third spray application and developed rapidly during the first part of July. By the middle of the month there was a large amount on the leaves and it was very common on the fruit. A certain amount of fungous leaf-spot also appeared. Russeting of the fruit, apparently resulting from weather conditions, was evident early in the season. It was noted that this russeted condition was confined to the upper sides of the fruits as they hung on the trees.

THE EFFECT OF THE DIFFERENT SPRAYS ON THE FRUIT IN 1916.

The fruit was harvested and sorted the first week of October. From the experimental plots in orchard No. 2 only the crop from the two central rows or 12 trees was saved for sorting. This was limited to a random sample of 20 barrels where the total crop of these central rows exceeded this amount. The following, Table I, gives the results obtained. The record for orchard No. 1, where plots 1 and 5 were repeated on a large scale was obtained by selecting a random sample of 20 barrels from each half in such a manner that it would represent as nearly as possible the average conditions throughout each part treated in a different manner. These results are given in Table II.

TABLE I.

Summary of Results Obtained from Sorting Fruits on Experimental Plots in Orchard No. 2 in 1916.

Plot.	TREATMENT.	Total number of apples.*	Number smooth.	Number scabby.	Number russeted.	Per cent of perfect apples.	Per cent of scabby apples.	Per cent of russeted apples.	Difference in per cent of russeting as compared with check.	Average yield per tree in pounds.
1	Standard dilution lime-sulphur plus 1 pound of dry, acid arsenate of lead to 50 gallons	8197	2678	61	5467	32.67	.74	66.69	46.12	215
2	Friend Calyx nozzle used. Otherwise like Plot 1	8434	3934	159	4359	46.64	1.88	51.68	31.11	265
3	Standard dilution lime-sulphur plus 1 pound dry arsenate of lime to 50 gallons	7417	5351	398	1688	72.14	5.36	22.75	2.18	276
4	Blossom bud application omitted, otherwise like Plot 1	8256	3804	111	4358	46.07	1.34	52.78	32.21	283
5	Blossom bud application, lime-sulphur 20 per cent stronger than standard, plus 1 lb. of dry, acid arsenate of lead in 50 gallons. Calyx and one later application. 2 lbs. of dry, acid arsenate of lead in 50 gallons of water	8174	4876	150	3188	59.65	1.59	39.00	18.43	324
6	Dry, acid arsenate of lead alone, 2 lbs. to 50 gallons of water	8548	5302	148	3144	62.02	1.61	36.78	16.21	357
7	Bordeaux mixture 3-3-50 plus 1 lb. of dry, acid arsenate of lead to 50 gallons	4338	1136	19	3183	26.18	.43	73.37	52.80	90
8	Sherwin-Williams Co. dry lime-sulphur, 3 pounds, 11 ounces plus 1 pound dry, acid arsenate of lead to 50 gallons	8469	3664	111	4709	43.26	1.31	55.6	35.03	191
9	Unsprayed check	6091	2931	2363	1253	48.12	38.81	20.57	0	122.5

*Omitting those apples counted twice as both scabby and russeted.

TABLE II.

*Summary of Results Obtained in 1916 from Sorting Fruits in Orchard No. 1.**

TREATMENT	Per cent of perfect apples.	Per cent of scabby apples.	Per cent of russeted apples.
East half. Sprayed like plot 1 of 1916	45.96	0.17	53.86
West half. Sprayed like plot 5 of 1916	56.68	1.24	42.11
Unsprayed Check. Plot 9 in orchard No. 2, 1916	48.12	38.81	20.57

*The per cents for each plot do not always total 100, since certain apples were counted twice as both scabby and russeted.

TREATMENT OF PLOTS IN 1917.

Plot 1. Thomsen's "T. P." arsenate of lead paste alone, 4 pounds in 50 gallons of water.

Plot 2. Corona dry, acid arsenate of lead alone, two pounds in 50 gallons of water.

Plot 3. Blossom bud application lime-sulphur 20 per cent stronger than standard, plus one pound of Corona dry, acid arsenate of lead in 50 gallons. Later applications two pounds of the same arsenate in 50 gallons of water.

Plot 4. Blossom bud application omitted, otherwise like plot 5.

Plot 5. Standard dilution lime-sulphur, plus one pound of Corona dry, acid arsenate of lead in 50 gallons.

Plot 6. Standard dilution lime-sulphur, plus one pound of Thomsen's dry arsenate of lime in 50 gallons.

Plot 7. Standard dilution lime-sulphur, plus two pounds of Thomsen's "T. P." arsenate of lead paste in 50 gallons.

Plot 8. Standard dilution lime-sulphur alone, no arsenical added.

Plot 9. Unsprayed check.

Plot 10. Sherwin-Williams Co. dry lime-sulphur 3 pounds, 11 ounces, and 1 pound of S-W Co., dry, acid arsenate of lead in 50 gallons of water.

The spray combinations used on plots 2, 3, 4, 5, 6, 9 and

10 in 1917 were the same as those used on plots 6, 5, 4, 1, 3, 9 and 8 respectively in 1916.

Two new features were included in the 1917 experiments in order to obtain farther light on the question of the fungicidal action of arsenate of lead in controlling apple scab. Plot 8 was sprayed with standard dilution lime-sulphur alone with no arsenical added, in order to secure a check on this point from another angle. On plots 1 and 7 a different form of arsenate of lead was used than that previously employed.

The writer's first observations indicating the possible value of arsenate of lead in controlling apple scab were made quite unexpectedly in 1912 in connection with this series of experiments. For the most part it has been the custom to utilize for experimental work the same supply as that bought for general use as an insecticide on the farm orchards. In the earlier work no attention was paid to the character of the material used, whether it was acid, neutral, or basic, or a mixture of two or more of these different forms. Samples were saved from the lots used in 1915 and 1916 and analyses of these samples by the Chemical Department of this Station showed that each, although purchased from different manufacturers, was practically of the same composition as a pure acid, or lead hydrogen arsenate. No accurate data is obtainable as to the composition of the materials used in former years. However, a study of the reports of analyses of the same brands as were used in these years, based upon samples taken by the inspection service from goods on sale in the State, shows that in all probability these results showing a fungicidal action on apple scab have been obtained throughout the series of experiments with an acid arsenate of lead, previous to 1917.

"Taken as a whole, the literature indicates that there are at least two common lead arsenates, lead hydrogen arsenate and lead orthoarsenate; that these two compounds are the main components present in ordinary commercial lead arsenate....."*

The authors of the publication just quoted made a very thorough chemical study of the subject of the arsenates of lead used in spraying. Among other things, they attempted to pre-

*Robinson, R. H. and Tartar, H. V. The Arsenates of Lead. Bul. Ore. Agl. Exp. Sta. 128, p. 6, 1915.

pare the orthoarsenate according to the methods recommended by certain other writers. What they obtained, as shown by analysis, did not correspond to a pure orthoarsenate of lead, since it contained more lead and less arsenic than the theoretical figures. Their tests led them to conclude that what they obtained was a distinctly different chemical compound, a new basic lead arsenate of which there was no previous mention in the literature. Furthermore, to quote farther, they state, p. 9: "Without going into any lengthy discussion of the reactions used, the authors will state that *lead orthoarsenate is not formed under the ordinary aqueous conditions employed in the manufacture of commercial lead arsenate, and that it is not a component of the commercial material as has been formerly supposed.* The compound present, which has been represented to be the orthoarsenate, is in reality the basic lead arsenic mentioned above." In a letter to the writer, under date of February 12, 1917, one of the authors (R) just quoted, stated that there are now on the market two brands of arsenate of lead which their analyses show to be of a neutral type and mentioned another which the manufacturers claim to be a neutral arsenate of lead.

Orthoarsenate of lead has been recommended as a safer material for use with lime-sulphur on peaches and has also been advocated for apple spraying. In view of the evidence cited above it would not be strange if some confusion should exist in the minds of those who are conducting spraying experiments as to what form of arsenate of lead they were using. In fact letters from 3 different horticulturists to the writer, two from Canada and one from another state, specifically stated that a certain brand put out by one concern is a neutral of orthoarsenate of lead. The chemists of this Station examined two samples of this brand in 1914 and 3 samples in 1915, taken in the open market in Maine. The arsenic content of these samples was such that they could have been by no possibility a neutral arsenate. The analyses do indicate that they were, in reality, fairly pure and consequently high grade acid arsenates. It is significant to note that the records indicate that the word "neutral" appeared on the label in 1914 and not in 1915. Moreover when asked in the winter of 1917 if they could furnish us with another form for experimental work this firm replied that

they could supply us only with what they claimed to be, and the Station's analysis showed to be, a very high grade acid arsenate.

Composition of Materials Used in 1917.

Through the cooperation of the Chemical Department of this Station analyses were made of certain materials, particularly the arsenicals used in the 1917 experiments. The dry arsenate of lead furnished by the Corona Chemical Company and the Sherwin-Williams Company showed a chemical composition of very closely the right proportions to conform to and but slightly lower in As_2O_5 and PbO than is the theoretical requirement for pure acid arsenate of lead.

The "T. P." arsenate of lead obtained from the Thomsen Chemical Company was in a paste form but since this discussion is concerned entirely with the type of the arsenate of lead used in the experiments the material, for convenience in making comparisons, was reduced to nearly a water-free basis before the analysis was made. The moisture content of the final or dry sample used was 0.22 per cent. On this basis 22.43 per cent As_2O_5 and 74.01 per cent PbO were found, the ratio being 1:3.299. Robinson and Tartar* point out that the theoretical ratio between As_2O_5 and PbO in an acid arsenate is 1:1.945 and in a neutral arsenate is 1:2.911. In their attempts to prepare a neutral or orthoarsenate of lead, an analysis of the samples obtained gave a ratio between the two compounds mentioned varying from 1:3.180 to 1:3.196. As has already been stated they expressed the opinion that arsenate of this composition is a basic and not an orthoarsenate. It will be noted that the ratio given by the analysis of the "T. P." arsenate shows even a greater deviation from the theoretical composition of an orthoarsenate.†

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l. c. p. 9.

†No attempt has been made to look up the analyses of this brand of arsenate of lead which have been made by the inspection service maintained by different states but one analysis of a sample in 1917 has come to the writer's attention. This is reported on p. 9 of Bulletin 315 of the New Jersey Agricultural Experiment Station. A sample of "Orchard Brand Powdered Arsenate of Lead—T. P." is reported as carrying 24.26 per cent of arsenic oxide and 71.72 per cent lead oxide. The ratio here corresponds fairly closely to the theoretical for a neutral or orthoarsenate.

In order to obtain as much light as possible upon the composition of this material certain definite questions regarding this point were asked of the manufacturers. The following is quoted from a statement made by their chemist:

"The T. P. product will contain about 3% to 5% $PbHAsO_4$. The remaining As_2O_5 and PbO are combined as either a mixture of $Pb_3(AsO_4)_2$ and some new basic arsenate, or entirely as the new basic arsenate, the composition of which, as far as the writer knows, has not been definitely determined."

The writer farther stated that while he was not familiar with the article of Robinson and Tartar that this new basic arsenate probably corresponds with the one they described.

TIME AND MANNER OF SPRAY APPLICATIONS IN 1917.

The dates of application in 1917 were May 30, June 20 and July 9, which shows a very abnormal situation. Previous to this the latest date for making the so-called "pink-bud" application, during 7 consecutive seasons, was May 24, and the earliest May 8. In the same period the second date, as determined by the fall of the petals, has been quite constant, usually not earlier than the third and not later than the sixth of June.

The method of application was the same as in 1916 except that a pressure of 200 pounds was constantly maintained by the spray pump.

CONDITIONS DURING AND FOLLOWING THE SPRAYING SEASON OF 1917.

The entire growing season, on the whole, was uncommonly cold, cloudy and wet. The very slow development of the flowers, and consequent delayed spray applications, was due to unseasonably cold, wet weather. Between the first and second applications of spray something over 9 inches of rainfall was recorded at the farm. On account of a leak which developed in the rain gage it was impossible to get an accurate record of the rainfall for June, but as near as could be determined it was over 10 inches. The observer estimates that over 4 inches fell in a single storm, June 10-12. The combined rainfall for May and June was about 12 inches. These conditions made it extremely difficult to control scab effectively.

Effect of the Different Sprays on the Foliage and Fruit During the Summer of 1917.

No evidence of scab could be observed on the foliage and fruit on any of the plots at the time of the second application, June 20. The orchard was not visited again till July 9 when the disease was present on the leaves in varying amounts on all plots. The following is a summary of the record on each for the season.

Plot 1. "T. P." arsenate of lead alone, double strength.

Scab became common on the leaves and fruit as the season advanced, but was very plainly less prevalent than on the unsprayed check. Relatively light leaf-spotting appeared about August 1 and a month later this was fairly common but there was little evidence of burning of the margins of the leaves.

Plot 2. Corona acid arsenate of lead alone, double strength.

The amount of scab was similar to the preceding, but leaf injury was somewhat more common.

Plot 3. First application stronger lime-sulphur and acid arsenate of lead; last two, double strength Corona acid arsenate of lead alone.

Throughout the season it was plainly evident that scab was more efficiently controlled on this plot than on the two preceding, which were sprayed with the two different forms of arsenate of lead alone. There was also less scab here than on plot 5, which received the standard treatment with combined lime-sulphur and arsenate of lead. Leaf injury was relatively somewhat more common than on the other two plots mentioned.

Plot 4. Standard dilution lime-sulphur and acid arsenate of lead; first application omitted.

Somewhat more scab was recorded for this plot during the summer than for plot 5. The most striking thing about it was the small set of fruit. As the fruit neared maturity the contrast shown by the number of apples on the trees on plot 4 as compared with those on plots 3 and 5 on either side was very evident. Unexpectedly, leaf injury was more common than on plot 5.

Plot 5. Standard dilution lime-sulphur and acid arsenate of lead.

The conditions observed on this plot throughout the season did not differ materially from those on plot 2.

Plot 6. Standard dilution lime-sulphur and arsenate of lime.

The records here were practically identical with those for plots 2 and 5.

Plot 7. Standard dilution lime-sulphur and "T. P." arsenate of lead.

The general condition of the foliage on plot 7 was decidedly better than was the case on any other in the series. At the close of the season only relatively small amounts of scab could be seen on the foliage and fruit and very little leaf injury was present.

Plot 8. Standard dilution lime-sulphur; no arsenical added.

The amount of scab on the leaves appeared about the same as on plots 2, 5 and 6. Only a very little leaf spotting and burning was observed and this was not apparent at the close of the season.

Plot 9. Unsprayed check.

Scab was very prevalent on the unsprayed plot from the time it first appeared. Injury to the margins of the leaves was also noted.

Plot 10. Sherwin-Williams Co. dry lime-sulphur, plus acid arsenate of lead.

Except for possibly slightly more leaf injury, very little difference could be detected between the condition of the foliage on the trees on this plot and on plot 5 where, on the last named, ordinary home-prepared lime-sulphur and a similar amount of arsenate of lead were used.

EFFECT OF THE DIFFERENT SPRAYS ON THE FRUIT IN 1917.

On account of the small crop, the sample taken for sorting included the fruit produced on the inside of the two outside rows as well as the middle two rows of each plot. Except on plots 4, 8, 9, and 10 from which 2, 8½, 5¼, and 5½ barrels respectively were obtained the sample varied from 12 to 20 barrels. The following Table III gives the results obtained from sorting.

TABLE III.

Summary of Results Obtained from Sorting Fruits. 1917.

Plot.	TREATMENT.	Total number of apples.*	Number smooth.	Number scabby.	Number russeted.	Per cent of perfect apples.	Per cent of scabby apples.	Per cent of russeted apples.	Difference in per cent of russeting as compared with check.	Average yield per tree in pounds.
1	Thomsen's "T. P." arsenate of lead paste alone, 4 lbs. in 50 gallons of water	9651	2535	7031	255	26.26	72.85	2.64	−4.72	111
2	Corona dry, acid arsenate of lead, 2 lbs. in 50 gallons of water	6835	1186	5605	135	17.35	82.00	1.97	−5.39	79
3	Blossom bud application lime-sulphur 20 per cent stronger than standard, plus 1 lb. Corona dry, acid arsenate of lead in 50 gallons. Later applications 2 lbs. of the same arsenate of lead alone in 50 gallons of water	9704	4032	5503	258	41.54	56.70	2.65	−4.71	125
4	Blossom bud application omitted, otherwise like plot 5	1163	134	1012	69	11.52	87.01	5.93	−1.43	15
5	Standard dilution lime-sulphur, plus 1 lb. Corona dry, acid arsenate of lead in 50 gallons	7240	2162	4893	380	29.86	67.58	5.24	−2.12	95
6	Standard dilution lime-sulphur, plus 1 lb. Thomsen's dry arsenate of lime in 50 gallons	7595	3731	3660	325	49.12	48.18	4.27	−3.09	124
7	Standard dilution lime-sulphur, plus 2 lbs. Thomsen's "T. P." arsenate of lead paste in 50 gallons	8703	4308	3877	713	49.50	44.54	8.19	0.83	142
8	Standard dilution lime-sulphur alone, no arsenical added	4168	1600	2188	607	38.38	52.49	14.56	7.20	59
9	Unsprayed check	4061	36	3995	299	.89	98.37	7.36	0.00	39
10	Sherwin-Williams Co. dry lime-sulphur, 3 lbs. 11 oz., and 1 lb. S-W Co. dry, acid arsenate of lead in 50 gallons of water	3509	1158	1950	673	33.00	55.57	19.17	11.81	40

*Omitting those apples counted twice as both scabby and russeted.

DISCUSSION OF RESULTS.

As has already been pointed out, the weather conditions both years, particularly during the early part of the season when infection occurs and the distribution of scab is most rapid, were exceedingly favorable for the development of the disease. The fact that nearly 39 per cent of the fruit on the unsprayed check plot in 1916 and over 98 per cent in 1917 were classed as scabby indicates that both seasons, particularly the last, provided conditions for a rigorous test of the spray mixtures used. The orchards were plowed early in May 1916, thus turning under the leaves of the previous season, except those that lay near the bases of the trees, before the ascospores of the fungus had developed. This undoubtedly materially reduced the possibilities of primary scab infection that spring. General observations indicated that scab developed with greater severity on unplowed and unsprayed orchards near by than it did on the unsprayed check plot, but no accurate data were obtained on this point.

It will be noted that during the first season under discussion every spray material used showed marked and some of them excellent scab control. On the other hand, the efficiency of the same materials in 1917 was exceedingly low. In the light of past experimental spraying work in the same orchard it is believed that the very abnormal weather conditions during the early part of the season, which materially delayed the first two applications, are primarily responsible for the poor results obtained the second season. Undoubtedly in practical work an additional, earlier application of a fungicidal spray when the leaves are about one-fourth inch in diameter, such as has been recommended by Brittain and Sanders as the result of their work in Nova Scotia, would be very effective in Maine under such conditions as these. This will be discussed farther under the topic, "The importance of the blossom bud application."

FRUIT RUSSETING ON THE PLOTS AS A WHOLE.

Much of the following discussion with reference to the desirable and undesirable qualities of certain spray combinations with regard to russeting would not apply in the same degree to a number of commercial varieties of apples. Attention is again called to the fact that the skin of the fruit used

in these experiments is particularly sensitive to any irritating influence, especially when the apples are small. This has been demonstrated repeatedly for the climatic conditions which prevail where the experimental orchard is located. In normal seasons a slight amount of russeting has always appeared on the unsprayed check plot and in the past this has been increased in varying degree by the different spray mixtures used. A comparison of the results obtained with reference to russeting, during the two seasons present some interesting and unexpected contrasts.

One of the most prominent facts shown by the tabulated results for 1916 is the relatively high per cent of russeted fruit on each plot, even on the unsprayed check which showed 20.57 per cent. This duplicated a condition which prevailed in 1913 when over 31 per cent of russeted fruit was obtained on the plot upon which no insecticide or fungicide was applied, and the different sprays produced a corresponding increase in amount. Although this russeting was materially increased by different sprays it is evident that much of it must be attributed to natural causes. The weather conditions of 1913 and 1916 were remarkably similar in many ways, and differed from *previous* seasons in which abnormal fruit russeting did not occur. In 1913 the first spray application was followed by a month of unseasonably, cold weather, with frosts and cold, north-west winds, associated with much cloudiness and heavy rainfall. In 1916 similar conditions prevailed previous to and following the first application. This was also followed in 1916 by heavy rains and continuous cloudy weather in June after the second application, which was not the case in 1913.

The amounts of russeting obtained in 1917 are contrary, in two respects, to what might be expected as the result of previous experience. While the weather conditions during the early part of the season were similar to those in two years mentioned above the amount of russeting was relatively slight as compared with that obtained then. What is still more remarkable, it will be seen that on 6 sprayed plots out of 9 there was actually less russeted fruit than on the unsprayed check. Only twice in the 4 preceding seasons, during which an unsprayed check plot had been kept for comparison, did anything like this occur. Each time it was recorded on a single plot and the dif-

ferences were slight, or within the limits of experimental error. The writer has no explanation to offer as to cause of these unexpected results. It is true that the dates of application in 1917 were much later than in 1913 and 1916, but they were made at a corresponding stage of the development of the flowers and fruit.

LIME-SULPHUR VS. BORDEAUX MIXTURE.

There has been, perhaps, little excuse to continue to include a plot sprayed with bordeaux mixture in these series of experiments. It was omitted in 1917. In the past it was retained solely for the purpose of serving as a check, along with the one sprayed with lime-sulphur and the unsprayed plot, for a standard of comparison with the other spray combinations. Regardless of seasonal conditions bordeaux mixture has invariably caused much damage to the Ben Davis variety on this farm, both by leaf injury and fruit russeting. Although almost perfect scab control has been secured, the per cent of perfect apples has been so reduced on account of russeting that spraying with bordeaux mixture has actually resulted in a loss rather than a gain. This is well illustrated when the record of plots 7 and 9 in 1916, Table I, are compared. Only a little more than half as many merchantable apples were obtained on plot 7 as on the one where no spray whatever was used.

In 1916, as in the past, lime-sulphur combined with arsenate of lead gave efficient scab control, as is shown by comparison of plots 9 and 1 where the amount of scab was reduced from nearly 39 per cent to less than 1 per cent. On the other hand the large amount of russeting which occurred where the lime-sulphur and arsenate of lead was used reduced the percentage of merchantable apples to less than was obtained on the check plot. In 1917, while scab control was far from efficient, the percentage of merchantable apples, as shown by comparing plots 5, 7 and 9, Table III, was increased approximately 29 and 49 per cent respectively by the lime-sulphur and arsenate of lead treatment.

The records over a series of years indicate that in most seasons, even on a variety like the Ben Davis where the skin of the fruit is easily injured, spraying with lime-sulphur combined with moderate amounts of acid arsenate of lead is profit-

able. It is only in exceptional seasons where a large amount of russeting occurs as in 1916, that there is little real gain, and actual loss of merchantable fruit may occur. These observations apply only to the value of the fruit as influenced by the use of lime-sulphur and do not take into account the effects of the spray in improving the general health of the tree, which cannot be overlooked in practical work.

It should be understood also that the above statements with reference to both bordeaux mixture and lime-sulphur refer only to the selling value of the fruit of the variety under consideration. With any variety equally subject to scab and less susceptible to spray injury there is plenty of evidence that spraying with either fungicide combined with acid arsenate of lead is, as a rule, exceedingly profitable. As a matter of fact if apples were sold on the basis of quality and not on the appearance of the skin, those obtained on the plots sprayed in 1916 with lime-sulphur and bordeaux mixture were nearly 100 per cent perfect. The only imperfections were the russeting of the skin. The fruit on these sprayed plots was larger and in every way more healthy than on the unsprayed check.

The single trial in 1917 of the "T. P." arsenate of lead combined with lime-sulphur indicates that as good or even better results may be obtained with this material than with the acid arsenate used in like manner. It will be seen on comparing plots 7 and 5, Table III, that on account of more efficient scab control approximately 20 per cent more merchantable apples were obtained where the "T. P." arsenate was substituted for the acid arsenate. It is interesting to note, however, that while the difference was slight, less russeting was obtained by the use of the acid arsenate. Compare also plots 1 and 2, Table III, where these two forms of arsenate of lead were used alone, double strength.

THE EFFICIENCY OF THE FIRST SPRAY APPLICATION.

The results here reported are for the fifth and sixth seasons in which a plot has been included in these spraying experiments where the application of lime-sulphur when the blossom buds were showing pink was omitted. It will be noted on comparing the figures obtained in 1916 on plot 4 with those for plot 1, Table I, that scab control was only slightly better

on the latter plot where all 3 applications were made. A more striking fact is that where the pink bud spray was omitted nearly 13.5 per cent more merchantable apples were obtained, due to the greater freedom from russeting.

The experience of the season of 1916 tends to confirm the opinion expressed by the writer in Bulletin 249 that it is not necessarily a foregone conclusion, under Maine conditions, that the spraying operations of the year are doomed to utter failure if no spray is applied till after the petals fall. Previous to 1917 in only one year out of 5 has anything approaching this been the case on these experimental plots. Three years out of 5 very little difference in scab control was obtained on the plots with and without the first application. The remaining season there was a little over 3 per cent increase in scab as a result of omitting the pink bud spray. On account of increased russeting, less merchantable apples were obtained 3 years out of 5 where all 3 applications of lime-sulphur were made. Doubtless this would not have been the case with a variety of apples where the skin of the fruit is less tender than that of the Ben Davis.

It will be seen on comparing the per cents of scabby apples obtained on plots 4 and 5 in 1917, Table III, that this was a season where the omission of the pink-bud application was a matter of much importance for over 19 per cent more scab was obtained by so doing. It strongly emphasized the fact, not always recognized by growers, that spraying is really a form of insurance and that even though the records obtained in this series of experiments so far, indicate that the pink-bud application may be omitted in certain seasons with little or no increase in the amount of scab resulting, such an omission may be a matter of considerable importance in controlling the disease.

It is not the writer's intention to imply by any of the above discussion that the results secured indicate that the pink-bud spray is ever unnecessary in Maine and that it ever should be omitted from the spraying program. It is intended to emphasize the fact that, if for any good reason no spray is applied till the petals fall, the chances of preventing infection, as shown by the results obtained over a series of years, are still good if the remaining applications of spray material are made as usual. Such would not have been the case in 1917 and undoubtedly still another fungicidal spray applied about the middle of May,

some days before the blossom buds showed pink, would have been advantageous. However, throughout this series of experiments, covering 8 successive seasons, no evidence has been obtained to indicate that under Maine conditions the period for making any single applicaton of spray for the successful control of apple scab is limited to a single day, or even two or three days, although the pink-bud and calyx applications should be made as closely to the specified times as possible.

ARSENATE OF LEAD AS A FUNGICIDE.

While previous results seemed to furnish fairly conclusive data relative to the fungicidal value of acid arsenate of lead in preventing apple scab, these here reported represent much more severe tests. In comparing plots 6 and 9 in 1916, Table I, it will be seen that by the use of arsenate of lead alone the amount of scab on the fruit was reduced from nearly 39 to a little over one and one-half per cent. This was the fifth consecutive season that the figures obtained from experimental tests in this orchard have shown that arsenate of lead alone has materially reduced the amount of scab on the fruit. Scab control on plot 6 in 1916 was nearly as efficient as was obtained on plot 1 where the standard lime-sulphur and arsenate of lead treatment was used. A more important fact which should not be overlooked is that with the arsenate of lead used alone nearly twice as many merchantable apples were obtained, due to the greater freedom from russeting.

A comparison of the results obtained on plots 2, 5 and 9 in 1917, Table III, also indicated that arsenate of lead showed considerable fungicidal value, even under the severe conditions of that season. However, the results were plainly much inferior to those obtained with the combined lime-sulphur and arsenate of lead spray.

ACID ARSENATE VS. "T. P." ARSENATE OF LEAD.

No definite conclusions can be drawn from the work of a single season but the records obtained in 1917 on plots 1 and 2, Table III, indicate that the "T. P." arsenate of lead possesses fully as great if not greater fungicidal properties than the acid arsenate since about 9 per cent less scab was obtained with it.

This view is strengthened by the fact that on plot 5 where the acid arsenate was used with lime-sulphur about 23 per cent more scab was obtained than there was on plot 7 where the "T. P." arsenate was used in like manner.

LIME-SULPHUR WITH NO ARSENICAL ADDED.

The marked fungicidal value of arsenate of lead when used alone suggested that it might contribute materially to the fungicidal qualities exhibited by the combined lime-sulphur and arsenate of lead spray. To secure data on this point in 1917 plot 8, Table III, was included in the experiments. The fact that about 52.5 per cent of scabby apples were obtained on this plot and only about 44.5 on plot 7 where the "T. P." arsenate was added to the same strength lime-sulphur might indicate that there is something in this hypothesis were it not for the fact that over 67.5 of scabby fruit was obtained on plot 5 where the acid arsenate was used in like manner. It will also be seen on comparing the figures obtained on plots 1 and 2 with those for plot 8 that lime-sulphur, standard strength used alone was decidedly more efficient than double strength arsenate of lead, both forms, used alone. No definite conclusions should be drawn from this single trial, however.

MODIFIED SPRAYING PROGRAM.

The modified spraying program such as was carried out on plot 5 in 1916, Table I, and plot 3 in 1917, Table III, in which lime-sulphur 20 per cent stronger than standard is used for the pink-bud spray, followed by double strength arsenate of lead for the two later applications, has now been tested for 4 consecutive seasons, in comparison with plots sprayed all 3 times with standard lime-sulphur and arsenate of lead, and double strength arsenate of lead alone, respectively. In addition plots 1 and 5 of 1916 were duplicated on a large scale in the orchard known as Ben Davis No. 1, see Table II.

The results obtained in scab control in 1916 on the experimental plots and in the large orchard were very uniform for each kind of treatment. Plot 1 and the east half of Ben Davis No. 1, sprayed according to the standard program, produced

.74 and .17 per cent of scabby apples respectively. Plot 5 and the west half of Ben Davis No. 1, sprayed according to the modified program, produced 1.59 and 1.24 per cent of scabby apples respectively. The slightly better results obtained with both methods of treatment in No. 1 may be due to the fact that the trees are smaller here with more open spaces, allowing better ventilation and better penetration of sunlight. In each instance a greater per cent of merchantable apples was obtained with the modified spraying program, than from 3 applications of the standard lime-sulphur and arsenate of lead combination . This was directly due to the smaller amount of fruit russeting with the former.

It has already been shown by comparison of the results obtained on plots 1 and 4 in 1916 that omission of the pink bud spray entirely, did not lead to a material increase of scab. Therefore it is not surprising that the amount of scabby fruit, obtained with the modified spraying program on plot 5, or 1.59 per cent, should be practically the same as where double strength arsenate of lead was used alone throughout the season on plot 6, which was 1.61 per cent.

These results and those previously secured which have to do with the same subject, taken together with those obtained in 1917, illustrate very well the difficulties which may arise if in apple spraying experiments one attempts to draw definite conclusions from work covering only a few seasons. It might seem that the necessity for using the stronger lime-sulphur for the pink-bud spray is not indicated by the results secured in 1916 or in the 4 or 5 previous seasons. During this period plots sprayed with the standard combinations of lime-sulphur and arsenate of lead showed but little better scab control than where the pink-bud application was omitted entirely. It is also true that 3 applications of double strength arsenate of lead alone produced during successive seasons very efficient scab control when compared with standard dilution lime-sulphur containing one pound of dry arsenate of lead in 50 gallons. In spite of all of this the writer has not felt ready to advocate that two or even three applications of double strength arsenate of lead alone should be depended upon for the control of apple scab in commercial orchards in Maine. In view of the fact that in *some* seasons in Maine, and in all seasons according to the expressed

opinions of observers in some other parts of the country, the period just before blossoming is especially favorable for primary scab infection, it seems wise to advocate the use of combined lime-sulphur and arsenate of lead at this time. We have shown that a lime-sulphur spray containing 20 per cent more than the standard dilution is more efficient in scab control and causes practically no more fruit russeting than the latter. Also it is evident from experiments made in past years that the majority of the fruit russeting produced by lime-sulphur comes from the calyx and later applications.

Except for the first sentence the above paragraph stands essentially as it was written before the results of the 1917 experiments, here included, were obtained. A comparison of the per cents of scabby apples and merchantable fruit produced on the various experimental plots in 1917, Table III, seems to justify the position taken.

It is interesting to note, also, that the modified spraying program used on plot 3, Table III, when compared with the standard lime-sulphur and arsenate of lead treatment used on plot 5 shows a decrease of almost 11 per cent in the amount of scab produced and an increase of over 11.5 per cent in the amount of merchantable fruit obtained. In fact it was only where arsenate of lime and the "T. P." arsenate of lead were used, plots 6 and 7, that a greater percentage of merchantable apples were produced in 1917, than was obtained on the plot where the modified spraying program was used. In view of the fact that on the unsprayed check over 98 per cent of the fruit was scabby and less than one per cent was merchantable, a more severe test of the modified spraying program could hardly be imagined.

The Ben Davis and the Baldwin varieties predominate in the orchards at Highmoor Farm. Fruit russeting on both of these varieties, when sprayed in the ordinary manner, as a rule materially reduces the value of the crop produced each season. For this and the following reasons the modified spraying program has been adopted there for the present for the commercial orchards. Its relative efficiency in controlling scab has been shown by the results obtained on the half of Ben Davis No. 1 so sprayed in 1916, and upon the experimental plots in repeated seasons. A more important consideration is that with this modi-

fied spraying program fruit russeting has been materially reduced and the percentage of merchantable fruit consequently increased. Similar results were reported to the writer by a few of the leading apple growers of the State who sprayed parts of their orchards in this manner in 1916.

CALYX NOZZLE.

It has been the aim in these series of experiments to develop more efficient spraying methods as applied to local conditions and not primarily to make comparative tests of materials and appliances. Nearly every year, however, it has seemed wise for one reason or another to include something of this kind, usually limited to a single plot. The Friend calyx nozzle was used on plot 2 on account of the fact that instances had been called to the writer's attention where it was stated that better control of scab was obtained from lime-sulphur applied with it than with the ordinary mist type of nozzle.

In comparing the results secured in 1916 on plots 1 and 2, Table I, it will be seen that slightly better scab control was obtained with the mist type of nozzle than with the semi-drive type. On the other hand, there was a difference of some 15 per cent in the amount of russeting, in favor of the latter. Whether this has any special significance it is impossible to say at present.

DRY LIME-SULPHUR.

There was nothing in the action of this material either season to indicate that it is anything different from what the manufacturers claim it to be. In fact the results secured with it, at the strength used, were quite similar to those secured with dilutions of home-made, liquid concentrates of lime-sulphur. In 1916 it was slightly less efficient in scab control, but in 1917 it was plainly more efficient. Compare plots 1 and 8, Table I, and plots 5 and 10, Table III. It will be seen also that the first season the spray made from dry lime-sulphur produced less fruit russeting, but the second year it caused considerably more. The per cents of merchantable apples were in favor of the dry lime-sulphur both seasons.

ARSENATE OF LIME VS. ARSENATE OF LEAD.

Arsenate of lime was used with the idea that when combined with lime-sulphur less injury to the foliage and fruit would result than is the case where arsenate of lead is employed in the same way. As has already been stated the reverse seemed to be the case with regard to foliage injury in 1916, and no differences could be noted between the effects of the two in 1917.

In 1916 a difference of only two per cent in russeting was obtained when the results from the plot where the arsenate of lime and lime-sulphur were compared with those from the check plot, while this difference where arsenate of lead was used was over 46 per cent. In 1917 the plots where these two treatments were applied produced less russeted fruit than the unsprayed check and the differences, although in favor of arsenate of lime, were within the limits of experimental error.

It will be seen that scab control was better on the arsenate of lead plot in 1916 but in 1917 the results were quite the reverse of this. Each season the percentage of merchantable apples obtained was decidedly in favor of the arsenate of lime. No data has been obtained relative to the fungicidal value of arsenate of lime used alone.

SPRAY TREATMENT AS INFLUENCING THE SET OF FRUIT.

Attention has already been called to the fact that the final set of fruit on plot 4 in 1917 was far below that of the plots on either side of it. There is nothing in the condition of the trees on these plots which could in any way account for this difference. In the writer's opinion the only explanation for the small crop on this plot is that it was in some way, directly or indirectly, concerned with the failure to make a spray application at the time the blossom buds were showing pink. This was the fifth season that a plot treated in this way had been included in this series of experiments and, with the possible exception of 1913, nothing of the kind had occurred previously.

A number of different observers have stated that loss of fruit set may often be traced directly to the fact that the scab disease may occur abundantly on the pedicels and that this causes the blossoms and young fruit to fall. Wallace in 1913

summarized the literature on this point.* While no direct observations were made it is a logical conclusion that infection of the pedicels of the blossoms and young fruits by the scab fungus was responsible for the poor set of fruit on plot 4 in 1917. However a careful analysis of the facts do not commit one to this conclusion without reservations.

The Department of Biology of the Station, for other purposes, is now making an annual record of the yield of fruit in pounds for each tree in all of the orchards. These figures for the past two seasons have been turned over to the writer and the average yield per tree of each plot in 1916 and 1917 are given in the last column to the right of Tables I and III. Plots 7, 8 and 9 of 1916 and 8, 9 and 10 of 1917 are made up of less vigorous trees and allowances should be made in comparing them with 1 to 6 in 1916, and 1 to 7 in 1917. Also the trees on 5 and 6 in 1916 and 6 and 7 in 1917 are somewhat larger and more vigorous, thus partially explaining the averge larger yields on these plots in both seasons. There seems to be no reason, however, why plot 4 in Table III should produce only 15 pounds per tree while plots 3 and 5 on either side of it should yield 125 and 95 pounds per tree, respectively, except the probable one that the fruit set on plot 4 was injured from infection of the pedicels of the flowers and young fruit by the scab fungus. On the other hand, the unsprayed check, plot 9, composed of much less vigorous trees, lying west of plot 4 with the corners joining, yielded an average of 39 pounds per tree. While it is true that the relatively low yield on plot 9 may also be due partially to pedicel infection by the scab fungus it is difficult to explain why two and a half times as much fruit was produced here, where no fungicidal spray was applied, than was the case where one out of three applications was omitted, even granting that the application omitted was the all important one. Moreover only 40 pounds per tree were obtained on plot 10 where the records show that scab was as well controlled as on plot 3 and much better controlled than on plot 5.

It will be seen on reference to Table I that in 1916 the average yield per tree on plot 4 on which the blossom bud application of lime-sulphur and arsenate of lead was omitted was even

*Wallace, Errett. Scab disease of apples, Bull. Cornell Agl. Exp. Sta. 335:552-553. Sept., 1913.

better than on plot 1 where all 3 applications were made. It was also slightly better than on the adjoining plot 3 where lime-sulphur and arsenate of lime was used for all 3 applications. As has already been stated the larger yield on the other adjoining plot, number 5, is partly due to greater vigor of the trees which compose it.